

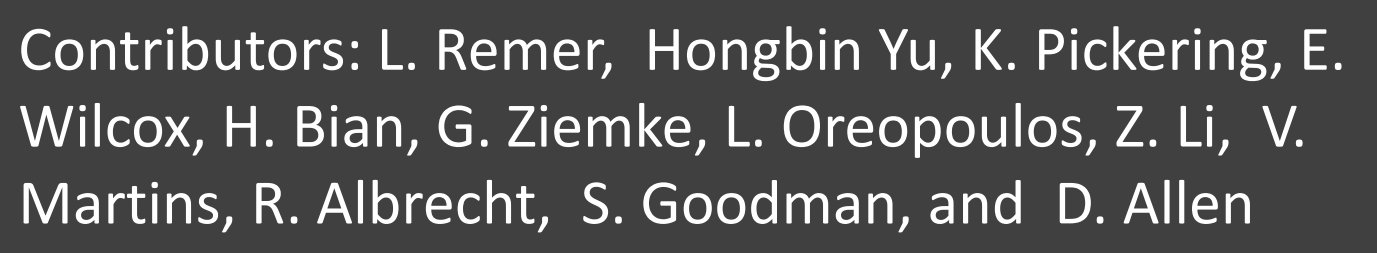


What does nature tell us about anthropogenic aerosol indirect effects?



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Two stories

I: Aerosol-shallow cumulus cloud interactions

II: Aerosol-deep convective cloud interactions

- We use two natural events (volcanic degassing) to examine aerosol-clouds interactions in two cloud regimes with satellite observations.
- The volcanic degassing events allow for a better separation of aerosol and meteorological effects.

Part I:

Aerosol interactions with shallow cumulus clouds

Introduction: Aerosol indirect effects on warm clouds

'Classic' view:

Twomey (1976)

Albrecht (1989)

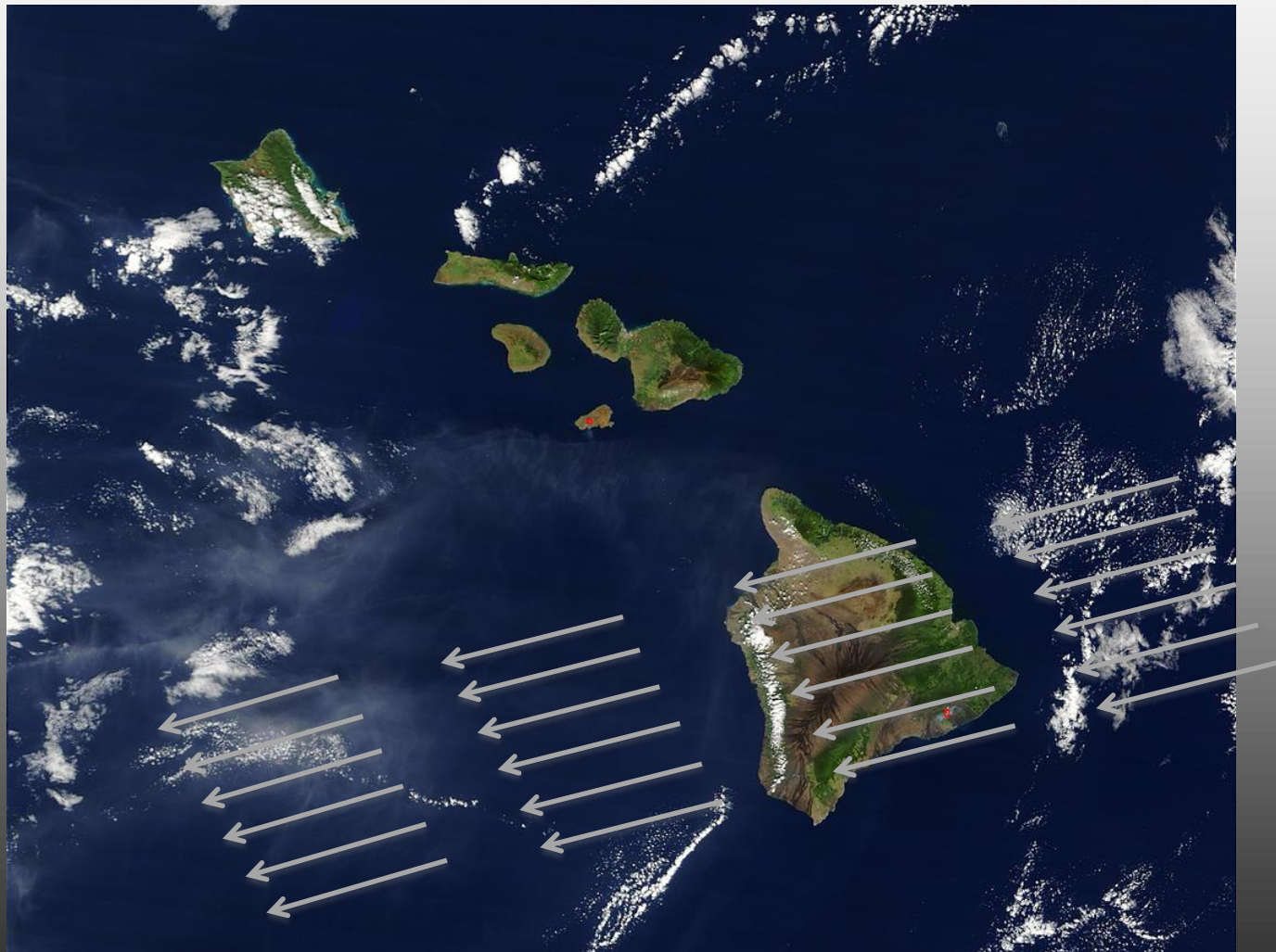
Other things (e.g., LWC) being equal, polluted clouds become brighter and may live longer because of less precipitation.

Updates:

Stevens and Feingold (2009), Rosenfeld et al. (2008), Khain (2009) and Tao et al. (2012), Wang and Feingold (2009)

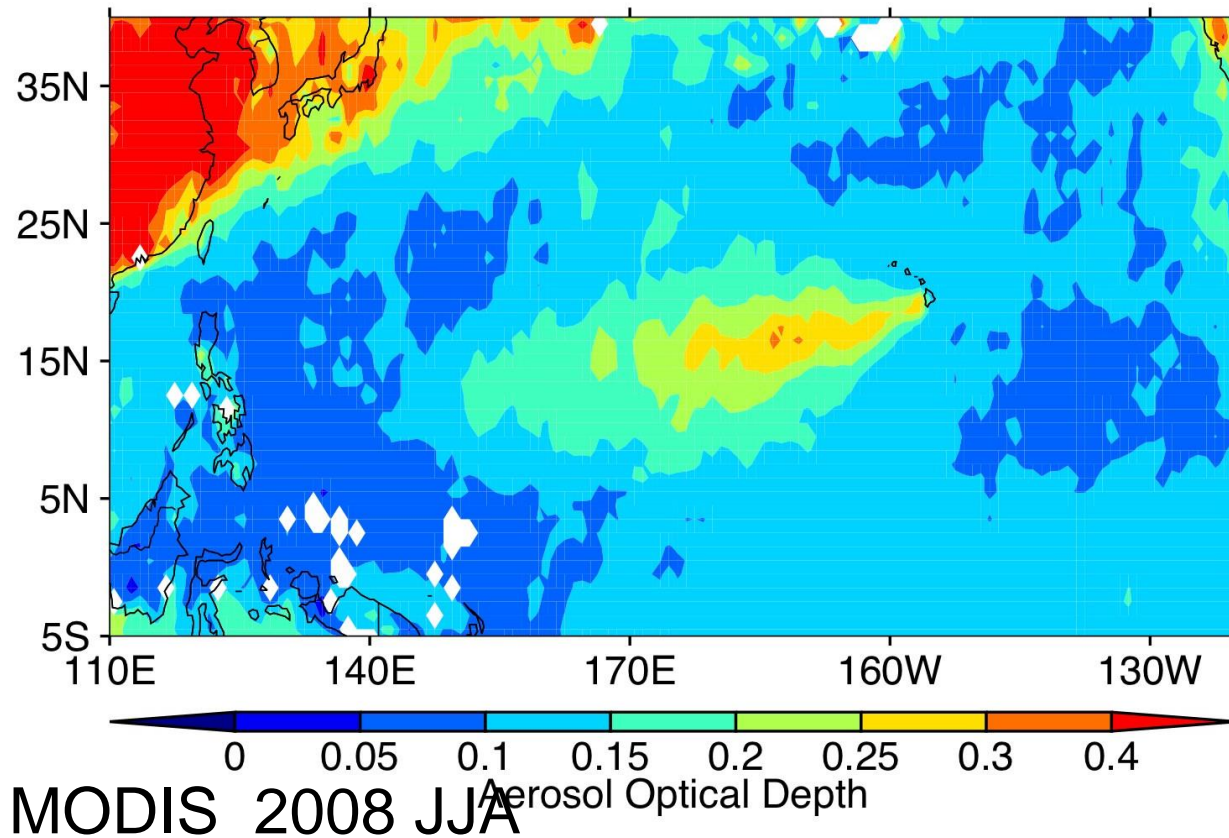
Other things are not equal.
Clouds adjust in various ways to initial aerosol perturbation.

The natural experiment

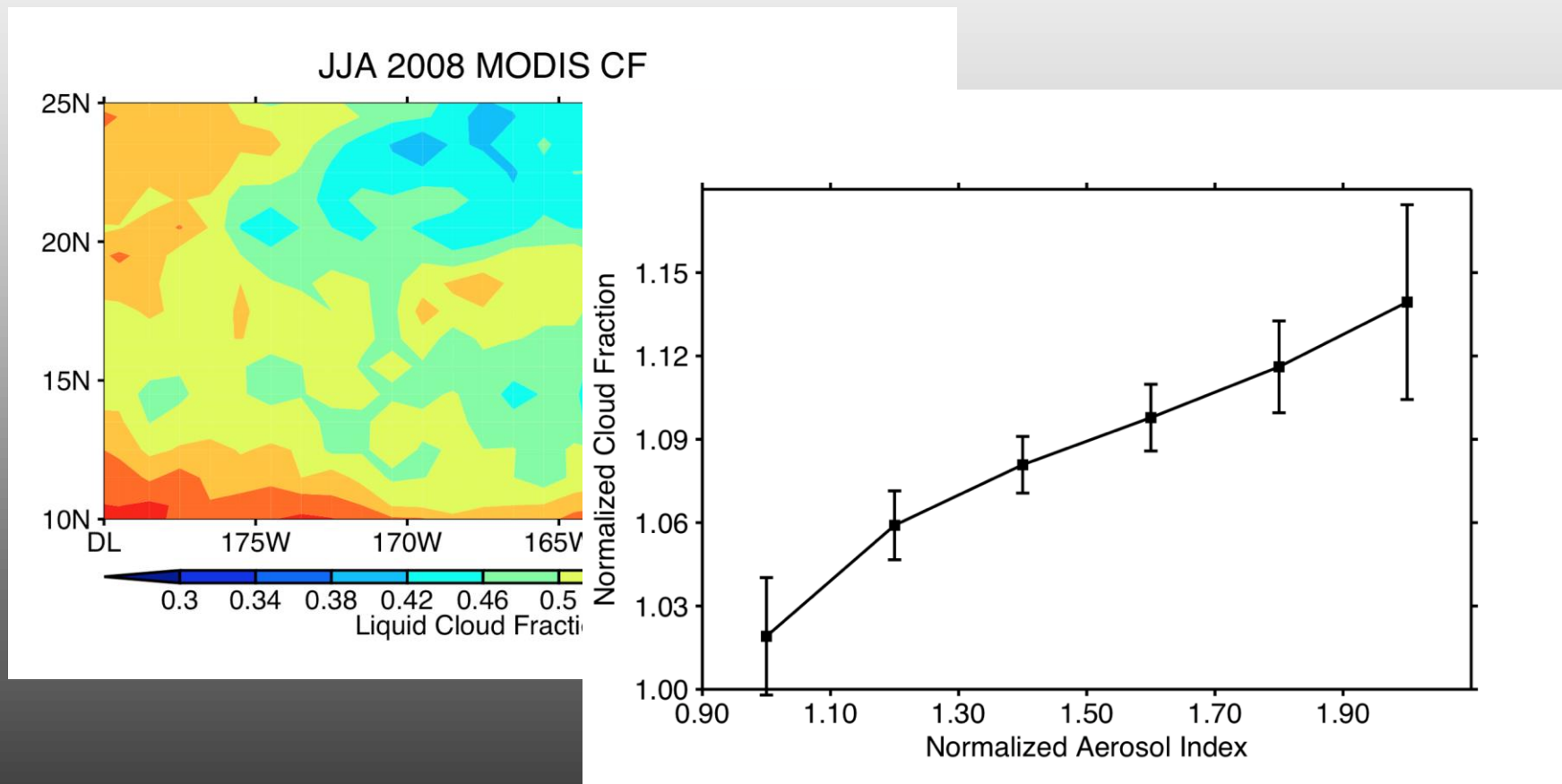


NASA MODIS

Volcanic aerosol plume

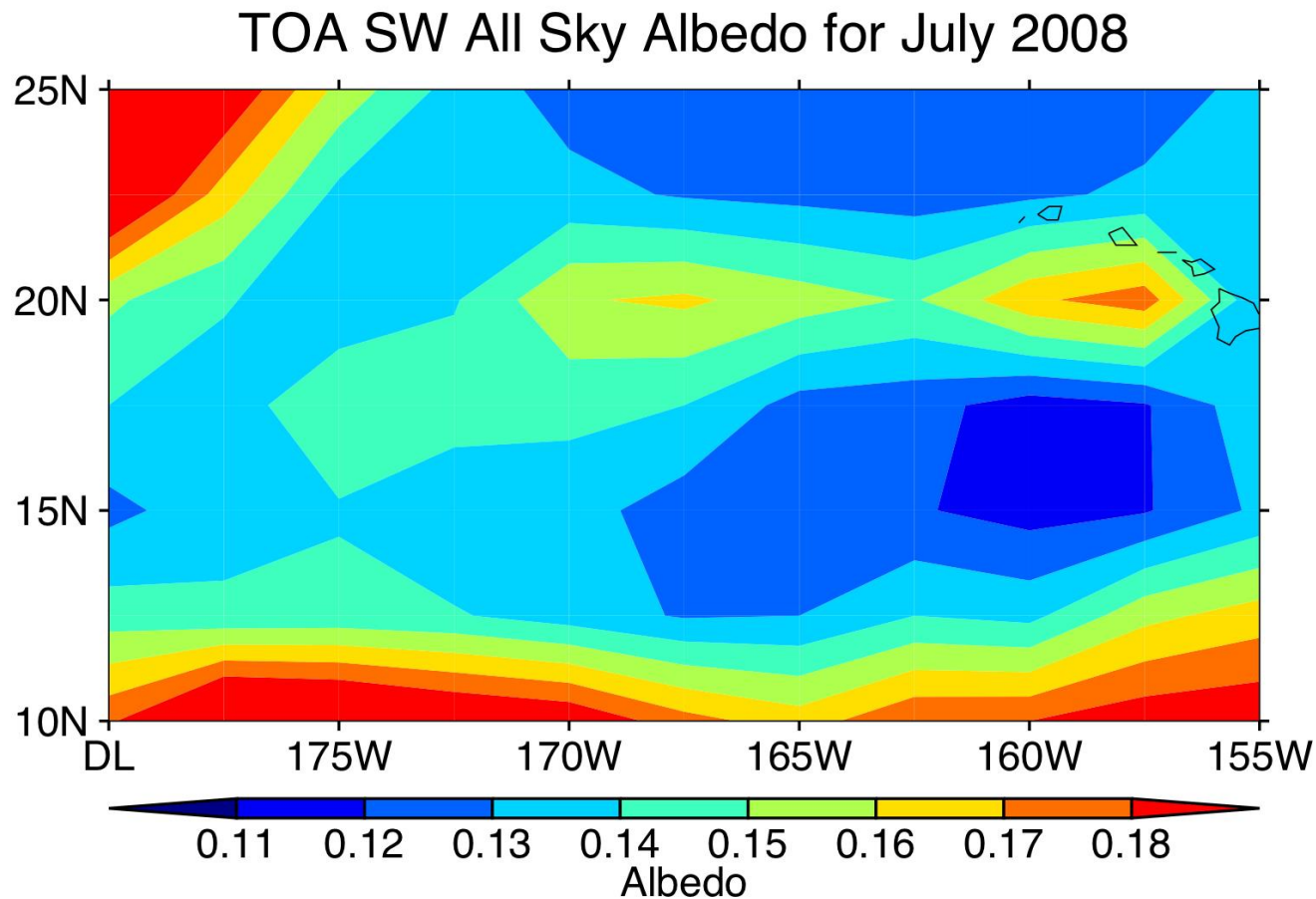


Aerosol increases cloud fraction



Holistic forcing

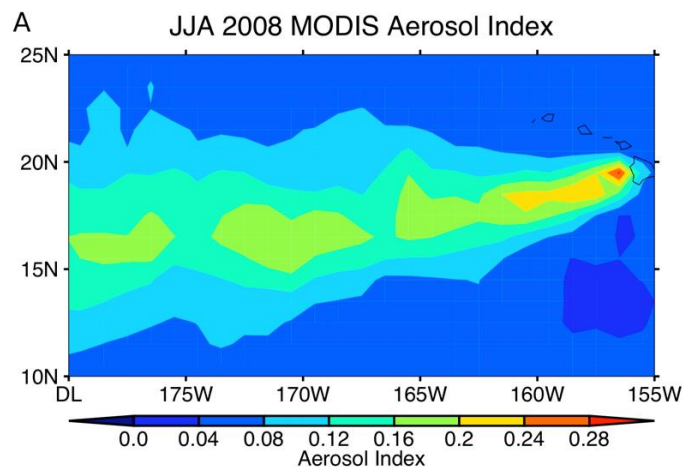
As large as 20Wm^{-2}
of forcing is
estimated.



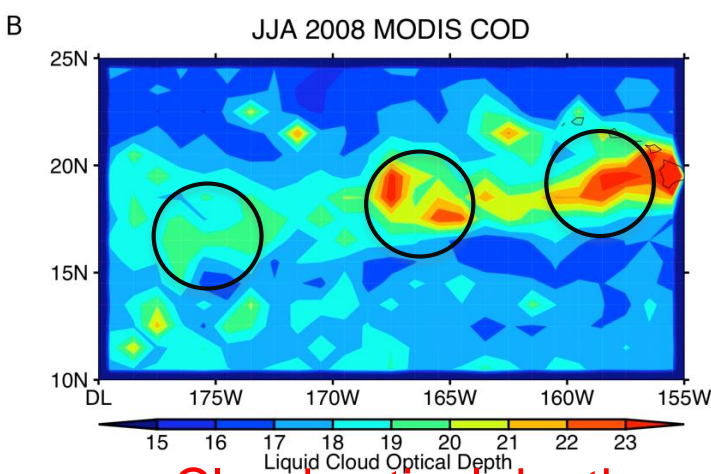
CERES SW Albedo at TOA

Large scale volcano tracks

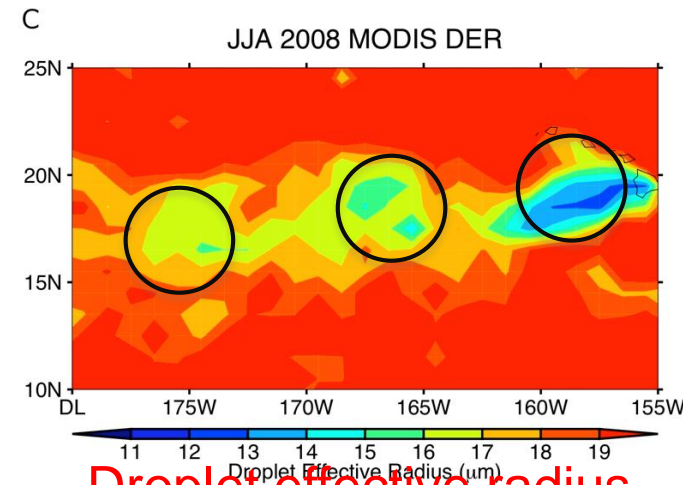
See details in Yuan et al. (2011)



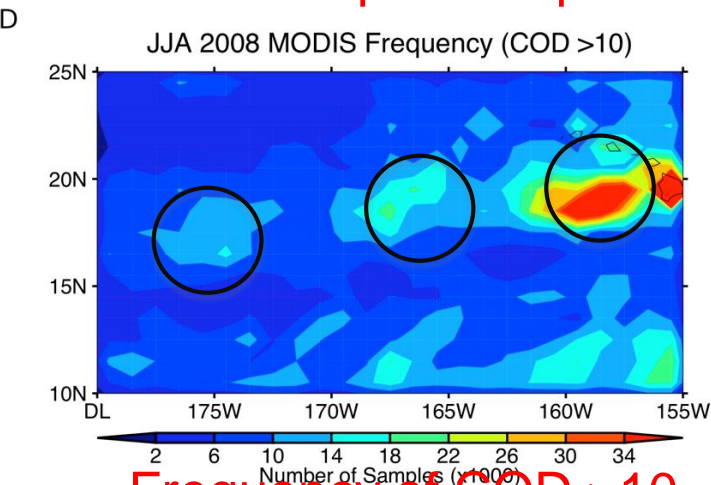
Aerosol index



Cloud optical depth



Droplet effective radius



Frequency of COD >10

Part I Summary

Aerosols

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graph TD; A[Aerosols] --> B[modify trade Cu microphysics]; B --> C[Suppress precipitation]; C --> D[Increase cloud amount]; D --> E[Large total indirect forcing];
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modify trade Cu microphysics

Suppress precipitation

Increase cloud amount

Large total indirect forcing

Part II:

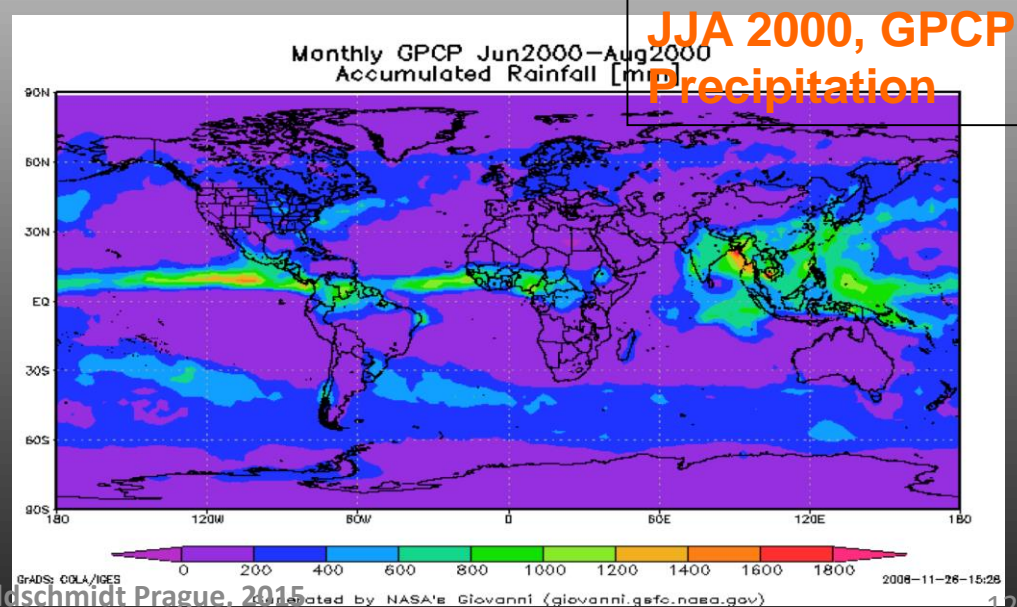
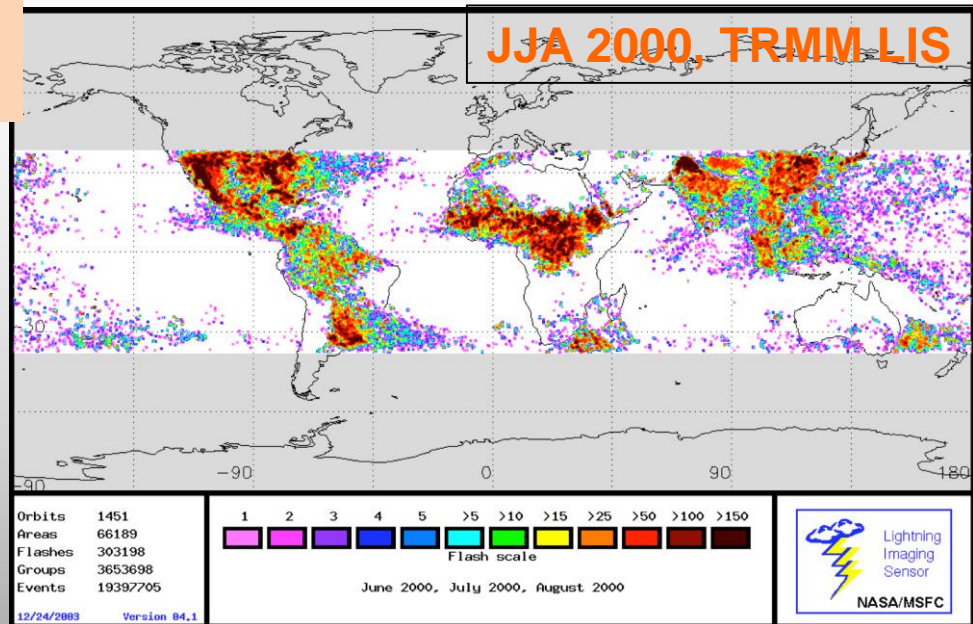
Aerosol interactions with deep convective clouds

The SLAC* conundrum

- Lightning as a proxy for strong convection.
- Rainfall amount as a proxy for convective activity.

Much more convection
but fewer thunderstorms
over ocean than over
land

*Scarce Lightning Ample Convection



Two hypotheses for SLAC

Thermodynamic and dynamic

Williams and Stanfill (2002); Williams et al. (2002). Williams and Santori (2004) Williams (2005)

- Higher Bowen Ratio over land
- Higher cloud base over land
- Lightning increases with island size

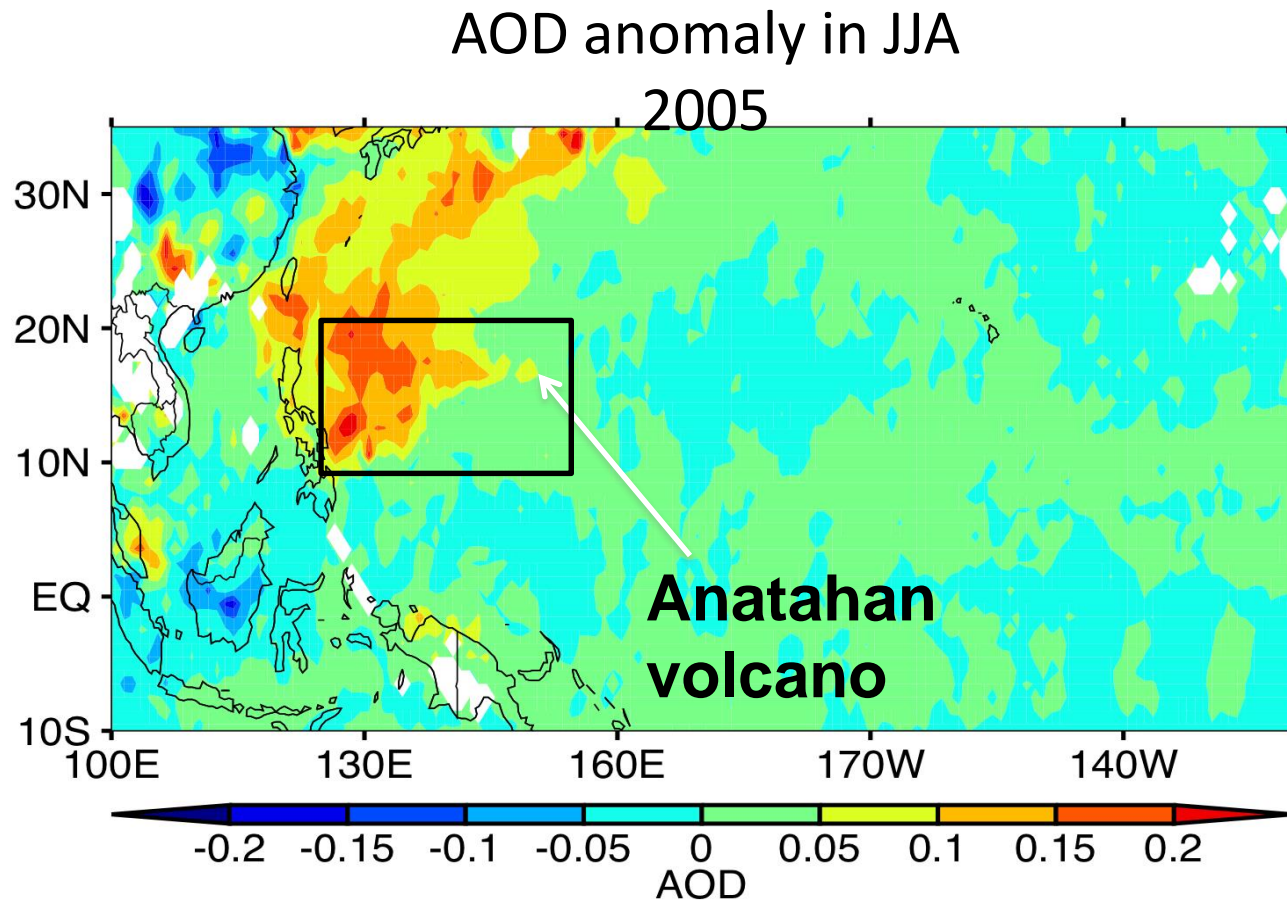
Aerosol

*Orville et al., (2001)
Lyons et al. (1998, Science);
Altaraz et al. (2010)
Sherwood et al. (2006)
Bell et al. (2008)*

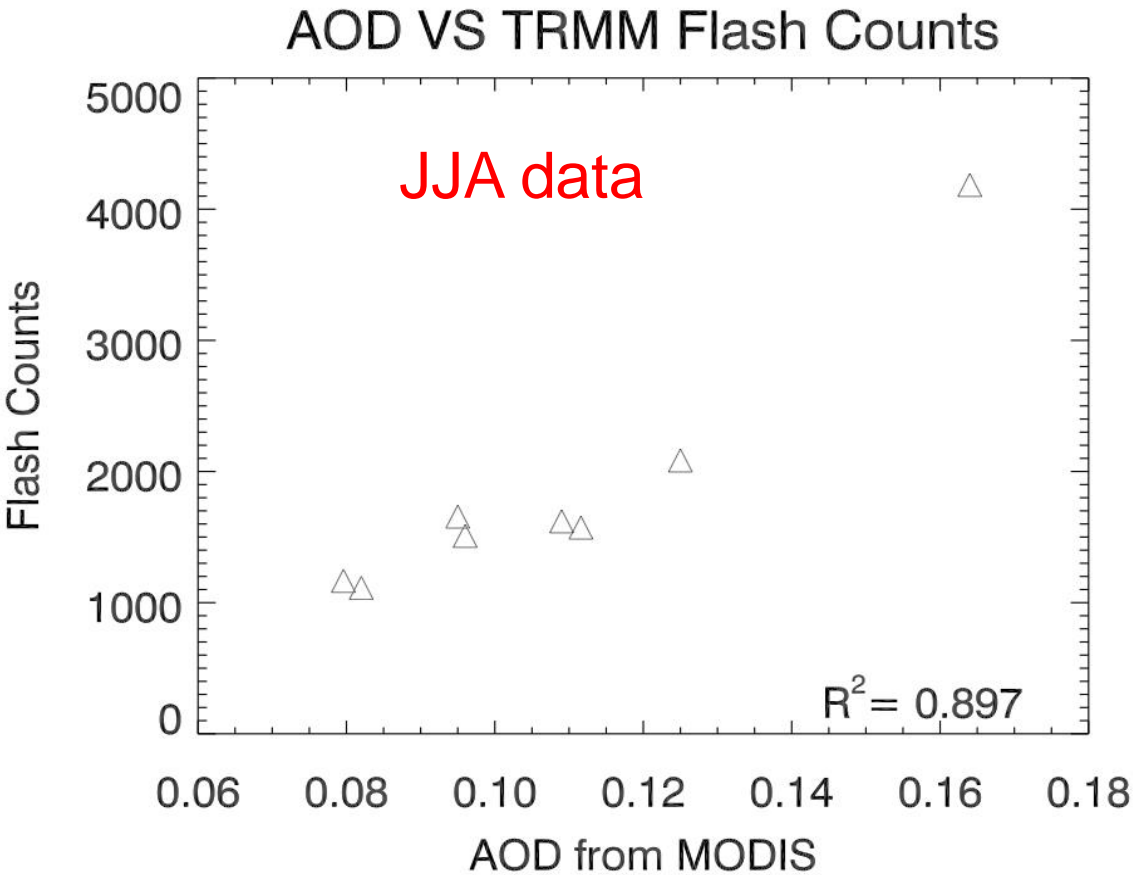
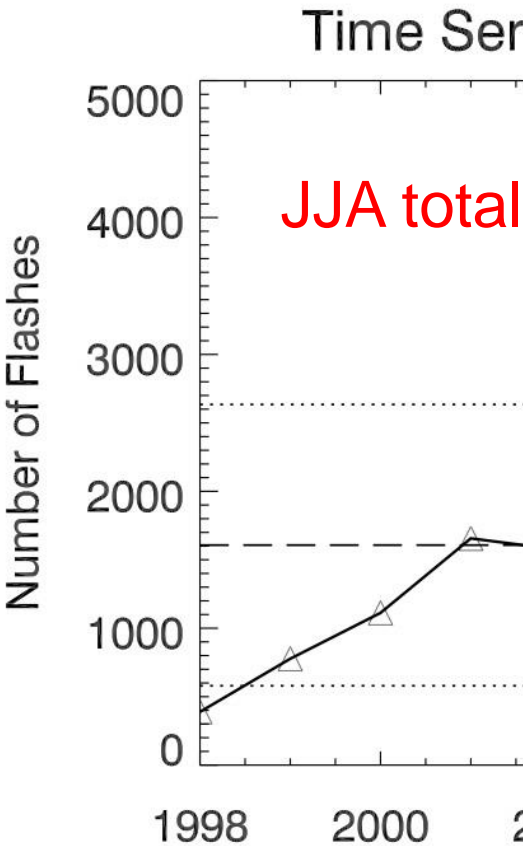
- More lightning over urban areas
- More lightning in smoky air
- Ice size smaller over land
- Weekly cycle

We use a natural experiment to avoid the convolution and examine aerosol invigoration

Our experiment



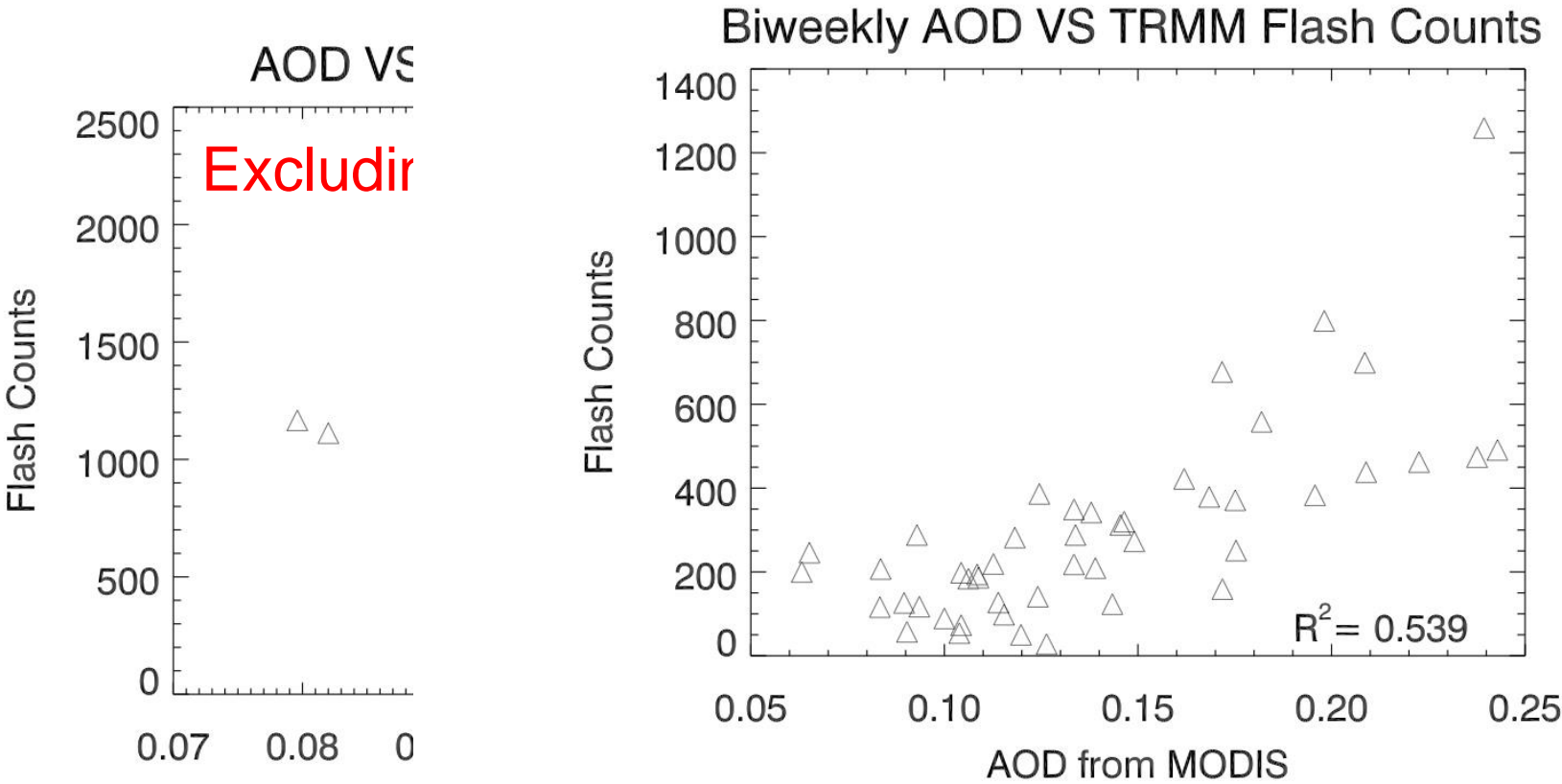
Aerosol increases lightning



Aerosol-lightning

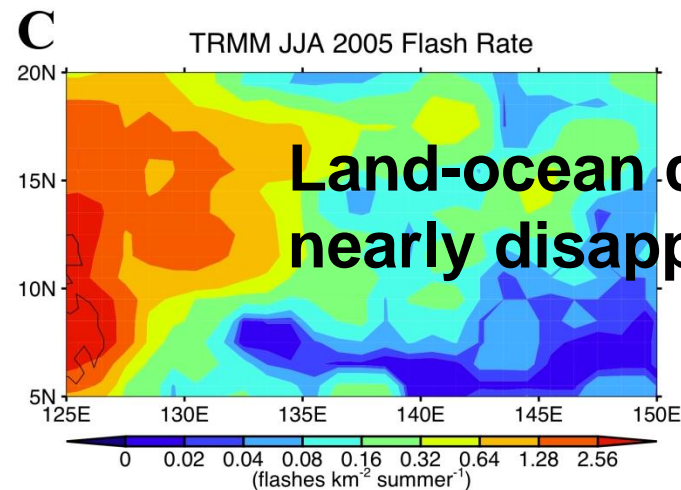
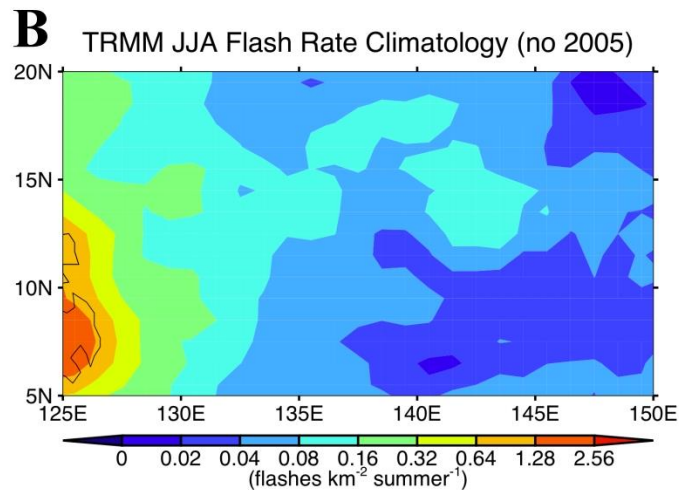
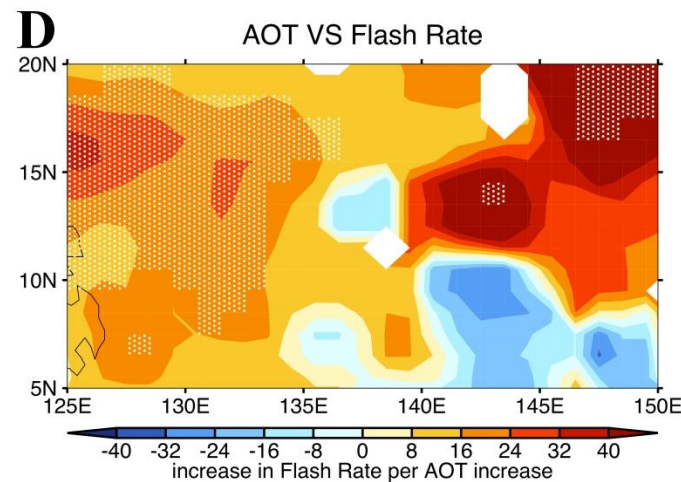
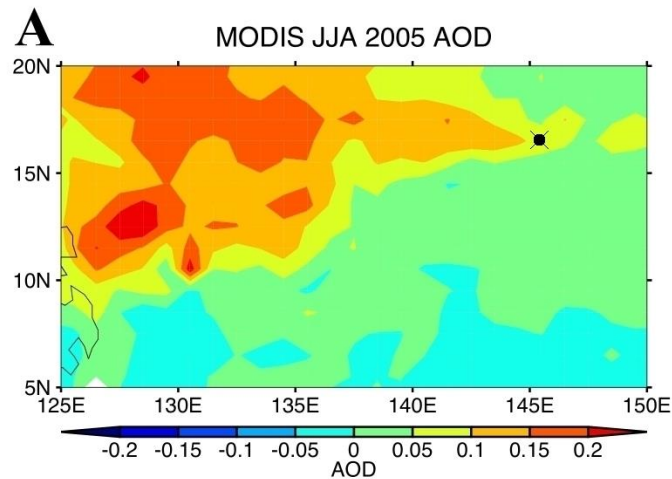
$P < 0.001$

Yuan et al. (2011)



Detailed view

1. Aerosols explain a big portion of land-ocean contrast
2. Maritime is highly sensitive to aerosol perturbations.



**Land-ocean contrast
nearly disappears**

*See details
in Yuan et
al. (2012)*

Part II Summary

Aerosols



Invigorate convection



More graupel and supercooled water



Increases charge separation



More lightning



Anthropogenic lightning

References

Yuan, T., et al. (2011): Observational evidence of aerosol enhancement of lightning activity and convective invigoration, *Geophysical Research Letters*, 38, L04701, doi:10.1029/2010GL046052.

Yuan, T., et al. (2011): Microphysical, macrophysical and radiative signatures of volcanic aerosols in trade wind cumulus observed by the A-Train, *Atmospheric Chemistry and Physics*, 11, 6415-6455, doi:10.5194/acp-11-6415-2011.

Yuan T., et al. (2012): Aerosol indirect effect on tropospheric ozone via lightning, *J Geophys Res-Atmos*, 117, D18213, doi:10.1029/2012JD017723.

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